Building Research Establishment Digest

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Honeycomb fire dampers

Intumescent paints, that swell to many times their original volume when heated, have been used for many years on flammable wallboards to prevent the surface spread of flame. A honeycomb base structure can provide sufficient surface area to support the weight of intumescent paint needed to close its cells. A honeycomb fire damper will permit an almost unrestricted flow of air through a duct or a transfer grille in a wall or door but will effectively close when subjected to the heat of a fire and will provide good insulation downstream from the fire.

The Building Regulations 1972 require that where ventilation systems pass through fire compartment walls or floors, or if they form part of a fire compartment wall, they must have a fire resistance of not less than half the minimum fire resistance of the wall or floor (Regulation E9(5) and (6)).

If the ventilation duct lies within a protected shaft, or if the shaft itself serves as a ventilating duct, then the duct must be fitted internally with automatic fire shutters to reduce the risk of fire spreading from one compartment to another (Regulation E10(9a)).

Mechanical fire dampers in various forms actuated by fusible-link have been available for many years and they operate rapidly once a fire occurs. Any mechanical device, however, requires careful maintenance if it is to give the standard of reliability that should be associated with fire protection devices. In common with other safety equipment, fire dampers must remain effective after many years often in inaccessible places and in conditions inimical to successful mechanical operation. With this in mind, the honeycomb fire damper was developed.

Intumescent paints

The honeycomb fire damper depends for its action on the property of some paints to swell to many times their original volume when heated. These paints were first produced commercially about a quarter of a century ago to prevent the spread of flame over flammable wall boards and for this they proved to be extremely valuable.

When heated, the paint film froths into a dough-like mass which, as the heating progresses, sets into a carbonaceous meringue having a volume which can be up to several hundred times the original volume of the paint film. The froth at once seals and insulates the surface that is being protected. The insulating properties of these paints naturally attracted attention in the hope that they might be used to increase the fire resistance of structures as well as reducing the surface spread of flame, but it was found not to be possible to produce a heavy enough paint film on the surface for the required insulating film; increasing the paint film thickness resulted in the paint layer falling slowly away from the surface as the film expanded and became mastic.

In 1970 experiments were started on the use of intumescent paints applied to honeycomb structures as the use of a honeycomb both increased the surface area available to carry paint at the same time that it provided a matrix to support the expanded film of paint. The applications of this work are the subject of patent applications; the dampers are being manufactured under licence by Fire Barriers Ltd, 70 Deacons Hill Road, Elstree WD6 3JG.

Painted honeycombs

It is a matter of simple geometry to show that for a honeycomb having a cell size d (measured across opposite flats) and a thickness t, the internal area covered by paint is $4\ t/d$ that of the plane area of the face of the honeycomb. For honeycombs as thick as the cell size the gain in paint weight is x 4 and for a cell size of 10 mm and a thickness of 50 mm the gain in paint weight is x 20.

It does not appear to matter whether the base material of the honeycomb is metal or paper because the honeycomb material is protected by the expanded paint. In fact, honeycombs of paper which are considerably cheaper than those of metal give a slightly higher fire resistance no doubt because of the higher thermal conductivity of metal.

Fire dampers

A honeycomb fire damper when open permits the free transmission of air, but once the honeycomb is heated the paint swells to fill the cells of the honeycomb and form a seal. Two types of damper have been tested in a vertical position for fire resistance according to the time/temperature curve specified

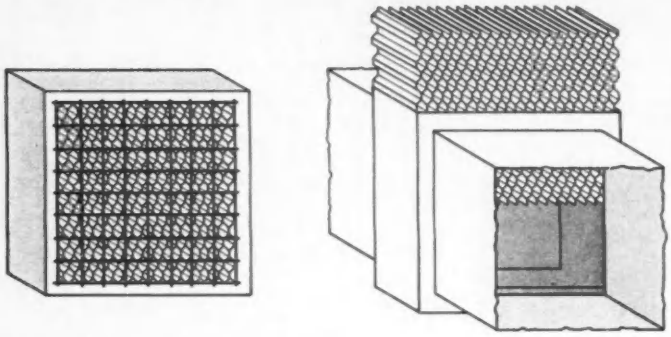


Fig 1 Honeycomb fire dampers
(a) wood-framed (b) metal envelope

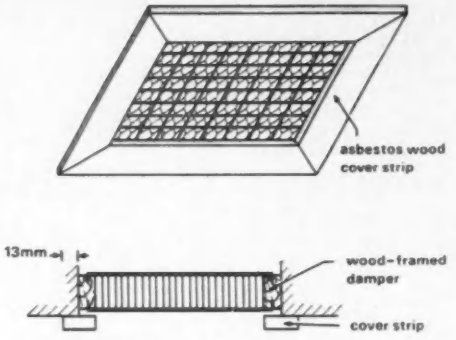


Fig 2 Damper fixed in ceiling

in BS 476 : Pt 8, one framed in wood and another in which the honeycomb is slipped into a metal holder.

Wood framed dampers Dampers framed in wood coated with intumescent paint (Fig 1a) were tested in sizes 228 mm square and 610 mm square; the honeycomb was protected on each face by a welded wire grille of 25 mm square mesh and the honeycomb was supported by metal ties between the grilles at approximately every 125 mm. The honeycomb of the 610 mm square damper was protected along its upper edge by an asbestos board cover extending for 12 mm into the honeycomb space. This type of damper is easy to construct and can readily be screwed into the wall of a duct.

Metal envelope dampers In this type of damper (Fig 1b) a metal slide, to contain the honeycomb, forms part of the duct wall. The honeycomb occupies the whole of the interior of the duct and there is no obscuration by framing. After a fire, the honeycomb can be readily withdrawn and replaced.

In a 50 mm thick damper with a 10 mm cell size (typical of a commercial product) the sequence of events during heating is as follows. The paint first swells on the furnace side of the damper and completely closes it in just over one minute. The paint then progressively swells throughout the thickness of the damper until at the end of 30 minutes the cells are blocked throughout the full thickness of the damper. Meanwhile the paint on the furnace side begins to become carbonised and attrition takes place until fire eventually penetrates along the upper edge of the damper.

The relationship between the weight of paint and the fire resistance is approximately T (minutes) = 13 W (kg/m^2). Hence, a fire resistance of one hour would be given by a paint weight of about 5 kg/m^2.

From this sequence of events it would be expected that the fire resistance of fire dampers would be additive and consequently dampers could be placed in cascade. This was tested by placing two one-hour dampers together and the fire resistance was found in fact to be rather more than two hours.

Practical fire tests

In addition to the BS 476 : Pt 8 fire resistance tests, a number of practical tests have been carried out in fire chambers 2·75 m x 3 m x 2·45 m high, carrying a fire load of 24·4 kg/m^2 composed of cribs of 25 mm and 40 mm wooden sections. The window areas of the compartment were such as to give severe fire conditions and the temperature of the fire at its peak was between 900 and 1000°C. The fire test was terminated at about 45 min as by this time the fuel had been consumed. The fire damper was built into one wall of the compartment and the combustion products of the fire were drawn through the damper at different speeds in the various tests.

Two proprietary paints were used in the tests which were made with honeycombs 50 mm thick with a cell size of 10 mm.

After the fire was lit the temperature in the compartment rose steadily to about 250° C when the damper closed. After this, the temperature behind the damper fell to below 100° C and remained at this level until the fuel was consumed. The paints differed in their performance in these tests. The better one formed a seal with the products of combustion being drawn through it at 10 m/s; it failed only towards the end of a test with a velocity of 15 m/s. The other paint was satisfactory only up to an air speed of 5 m/s.

Horizontal operation

The honeycomb apertures close equally well whether the damper is in the horizontal or the vertical position, but care must be taken to support the honeycomb of horizontal dampers adequately otherwise when the paint becomes mastic the honeycomb will sag under its own weight and gaps may be formed at the sides. Proper support can be achieved in the manner shown in Fig 2.

Toxic considerations

In some of the fire resistance tests a search was made for toxic products resulting from the thermal degradation of the damper material. As this consists of carbo-hydrates and ammonium phosphate it would be expected that ammonia and water would be evolved on heating and these products were found though not in quantities that would be

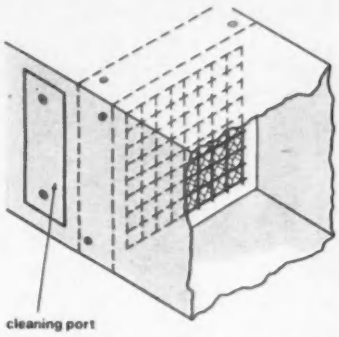


Fig 3 Wood-framed damper in duct

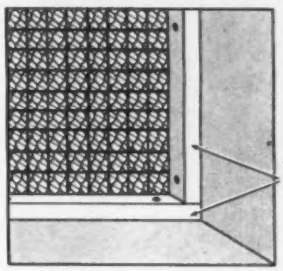


Fig 4 Damper in fire-resisting wall

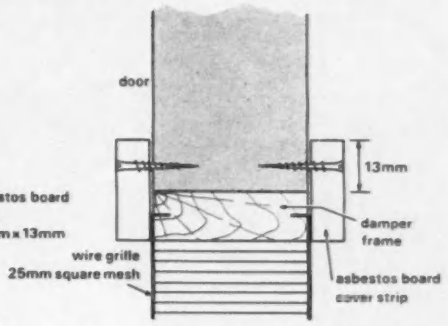


Fig 5 Fixing damper to door

biologically significant. A search was also made for hydrogen cyanide but none was found and tests for phenol revealed only a trace.

It would, of course, be surprising if significant levels of toxic products were found as the paints have been in use as flame-retardent treatments for the last 25 years.

Life of honeycombs

The chemical compounds used in the manufacture of honeycombs are stable and not likely to deteriorate with time. Tests at the Fire Research Station on painted samples of wallboard exposed on corridors showed no change in their fire performance after four years; a sample withdrawn from a building about to be demolished still performed satisfactorily under test after 15 years.

Resistance to air flow

The pressure drop across a honeycomb 50 mm thick and with a cell size of 10 mm, covered by a wire grille, is 9 N/m^2* at an air speed of 5 m/s. This low figure is no doubt due to the fact that the honeycomb apertures are aligned to the direction of the air flow and thus have a straightening effect.

The 'free area' of the honeycomb may be deduced by finding the volume of the material of the honeycomb and comparing this with the overall volume of the honeycomb; this amounts to 88 per cent.

The wood-framed honeycomb offers more resistance to air flow than the honeycomb itself because of the restriction of the frame and wire grille. The extra pressure loss due to the restriction of the frame amounts to 0·2 of the velocity head (assuming a 25 mm wide frame to a 610 mm square damper). The total loss in pressure for various air velocities is given in Table 1.

Although the pressure loss across a honeycomb at various air speeds gives the best indication of its effect on the flow of air in a duct, designers may need to know the 'free area': if allowance is made for the frame as well as the honeycomb, the free area is 74 per cent for this size of honeycomb.

* 1 N/m^2 = 0·102 mm, or 0·004 in., water gauge

Table 1 Pressure loss across framed fire dampers

Air speed	Pressure loss					
	due to honeycomb and wire grille		due to frame		total	
m/s	N/m^2	*in. wg*	N/m^2	*in. wg*	N/m^2	*in. wg*
1·25	1·5	*0·006*	0·2	*0·001*	1·7	*0·007*
2·5	3·4	*0·014*	0·7	*0·003*	4·1	*0·017*
3·75	7	*0·03*	2	*0·008*	9	*0·04*
5·0	9	*0·04*	3	*0·01*	12	*0·05*
6·25	12	*0·05*	5	*0·02*	17	*0·07*
7·0	15	*0·06*	7	*0·03*	22	*0·09*

Mechanical strength

The honeycomb when painted has great strength along the axis of the apertures. A paint weight such as would give a fire resistance of one hour would give the honeycomb a crushing strength of 1·9 $\times 10^5$ kg/m^2.

Dirt, moisture and industrial conditions

The intumescence of the paint is not affected by fluff or oil spray, nor is it affected by an atmosphere containing 5 per cent of sulphur dioxide, irrespective of whether the atmosphere is dry or has a relative humidity of up to 95 per cent at normal room temperature (18° C). The dampers ought not to be used, however, in conditions such that water may condense on them as this could lead to salt migration in the paint and this would interfere with correct closure.

Fixing

In ducts Wooden-framed dampers may be fixed directly into ventilation trunking by screws. Two rows of screws should be used so that the damper remains anchored whichever face is attacked by fire and there should be not less than two screws in each side extending to three-quarters of the thickness of the frame (Fig 3).

Cleaning ports should be provided for the removal of any material that would otherwise obstruct the flow of air. Greasy dirt may be cleaned off the damper with white spirit, the damper being withdrawn from the duct during cleaning to prevent an explosive atmosphere being formed within the duct.

Honeycomb dampers in metal holders are easy to withdraw and clean.

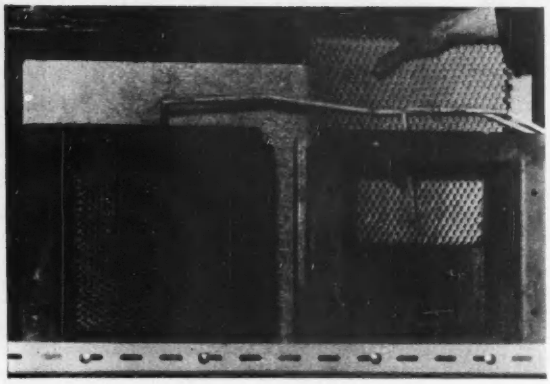


Fig 6 Honeycomb being placed in duct for test

As transfer grilles in walls In some ventilating systems air is required to pass through a fire resisting wall as part of the air distribution system or, in some instances, an air supply is required for combustion, as for example in a boiler room. As the damper may be only 50 mm deep, it can readily be accommodated in the thickness of a wall. The heavy coating of intumescent paint on the frame will expand and help to prevent the fire exploiting the joint between the wall and the damper. To increase the safety margin, a fillet of asbestos wallboard should be fixed to cover the joint between the wall and the frame on both sides of the wall (Fig 4).

As transfer grilles in doors Dampers may be included in fire resisting doors in order to transfer air; they should preferably be placed in the upper part of the door so that they close as early as possible in fire conditions. To avoid exploitation of the joint between the damper and the door by fire, this should be covered with a fillet of asbestos as shown in Fig 5.

Partitions and doors

Although most of the work with honeycombs has related so far to their use as fire dampers, it will be seen that if plane faces are attached to the honeycomb—and the intumescent paint on the honeycombs has been used as an adhesive for this purpose—a lightweight fire-resistant partition is formed. With hardboard faces, the weight of the partition would be about one-third that of the lightest conventional partition of equivalent fire resistance. Tests so far have been limited to small panels, about 1 m square. Obvious applications would be in the larger passenger-carrying aircraft of the future, hovercraft and other high-speed transport systems in which it is necessary to reduce mass as far as possible. Such partitions might also be used in buildings in which movable walls could give flexibility in layout, for example, to meet the need for changes in the home as families grow.

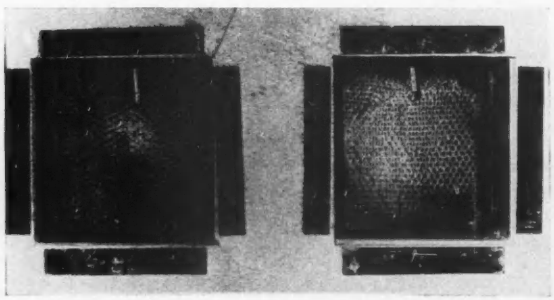
The controlling factor in the fire resistance of a partition or door of this construction is the weight of paint per unit plane area of the surface.

The fire resistance of a partition is related to its thickness since the partition must be thick enough to carry the weight of paint necessary for the required fire resistance without the paint rolling out of the honeycomb as it intumesces. For partitions with hardboard faces, if the paint weight W is expressed in kg/m^2, the fire resistance T (minutes) $= 3(4\,W+3)$. Thus a paint weight of about 4·3 kg/m^2 would be sufficient for a fire resistance of one hour. For doors, rather less paint is necessary because the insulation criterion is waived and $T = 4(4W+3)$; a paint weight of 3 kg/m^2 would therefore give a fire resistance grading of one hour.

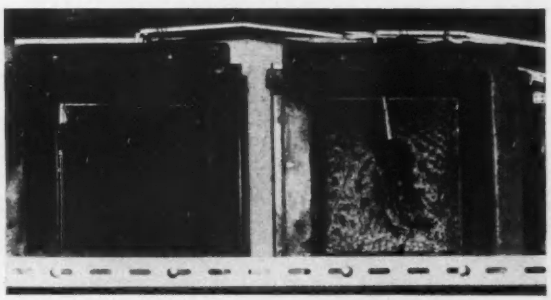
Summary

Intumescent honeycomb fire dampers can provide an effective fire barrier for air speeds up to 10 m/s; they provide insulation so that the temperature downstream from the fire is kept below 100° C and this could be a useful property in some situations. They should not be used in conditions in which they are likely to become wet, either by condensation or other cause.

Fig 7 Dampers after test
(a) seen from furnace side



(b) seen from unexposed side



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